Original Research Article

Filter design and applications in image improvement

Abstract:

This work presents the performance analysis of different basic techniques used for the image restoration. Restoration is a process by which an image suffering fromdegradation can be recovered to its original form. Removing blur and noise from image is the scope of this work. The work implemented different techniques of image enhancement and noise removal. The degraded images have been restored by the use of different filters.

The MATLAB code possesses an extensive set of algorithms for digital image processing. The code has arithmetic menu commands for performing versatile operations onthe images. The MATLAB code provided up-to-date high-quality images by designing formula commands supported by all standard mathematical functions. This open source code was used for imaging enhancement and deblurring.

Keywords: MATLAB code; Neutron imaging; filter design.

1. Introduction:

The task of deblurring, a form of image restoration, is to obtain the original, sharp version of a blurred image[1-3]. The goal of filtering is to eliminate as much noise and retain as much signal as possible.Most of filters are characterized by cut-off frequency and order parameters. The cut off frequency defines the frequency from which higher frequencies will be suppressed and therefore denotes the bandwidth of the filter. The amplitude of the filter at the cut-off frequency is dependent on the type of the filter such as Butterworth and Gaussian. The filters are defined by a second parameter, the order of the filter. This parameter tunes the filter by changing the slope of the filter function and allows the user to optimize the tradeoff smoothness– sharpness of the image[4-5].

This work presents mathematical techniques for high quality image. The techniques are based on applying low-pass imaging filters for removing highfrequencies. Low-pass filter, Gaussian filter and Butterworth filter were used for image improvement. Additionally, this workpresented a new technique for imaging processing and deblurring.

2. Neutron Radiography Facility:

All activities performed within the frame of this work have been performed at the neutron radiography facility (NRF). An overview of the main characteristics of this facility is given Table (1).

Table 1.The main characteristics of the NRF.

Parameter	Value
Reactor nominal power (MW)	22
Neutron flux density [n.cm^{-2}s^{-1}]	~1.5*10^{7}
L/D ratio	117.3
Cadmium (Cd) ratio	10.26
Beam outlet diameter [cm]	20
γ-background at the full power [Sv/h]	5.5
strength of the neutron source [n/s]	28*10^{8}

Fig. 1 represents the geometric model of the NRF. It comprises from:

1- Reactor core as a stationary planar neutron source,

2- Gamma ray lead filter to reduce gamma intensity emerged with the neutrons,

3- Divergent aluminum collimator, submerged into the water of the reactor tank. The collimator is internally lined by 2 mm thickness cadmium (Cd) sheet. The function of the collimator is to collimate thermal neutrons,

4- The irradiation conduit. It is cut cross the biological shield and internally lined with 2 mm Cd sheet, its function is to contribute with the collimator to get well defined beam,

5- The lead beam shutter.

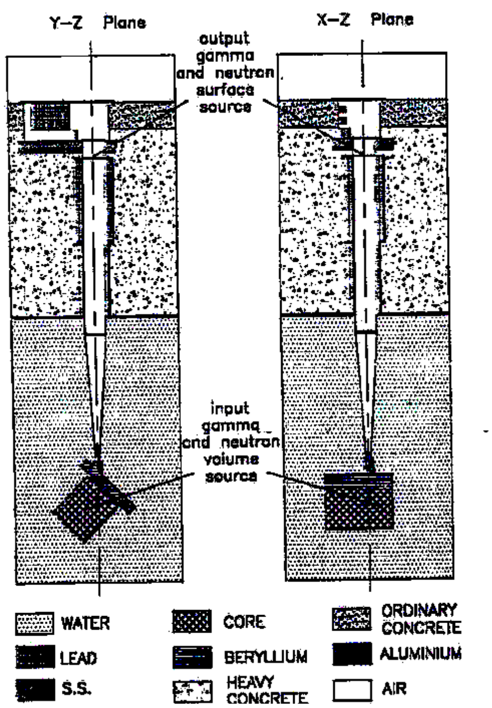

Fig.1. Geometric model of the NRF.

2.1 Neutron imaging (NI) system:

Digitization of the NRF has the potential to improve the performance of the neutron radiographic investigations.A high-resolution, 14-bit charged-coupled device (CCD) [6] cooled camera system, was installed recently at the NRF. This camera exhibits a superior resolution with advanced thermo-electrical technology in CCD ships cooling. Table (2) highlights the main parameters of the CCD-camera.

Table 2.Main parameters of the CCD-camera.

Parameter	Value
Pixel array format (horizontal x vertical) pixel	2048*2048
Sensitive Area [mm]	200 x 200
Pixel Size [μm^2]	7.4 x 7.4
Digitization (Dynamic Range)	14 bit (32768 gray levels)
Dark current (e^-/pixel.s)	0.5
Image Frame Rate (Frame/Sec.)	14.7
Exposure Time	5 µsec. to 49 days
Data interface	IEEE1394a
Cooling Method	Peltier cooler to -50 degree versus ambient temperature

2.2 The degradation model:

The simple equation for expressing image blurring/degradation is as follows [7];

$$\boldsymbol{g = f * h + \eta} \tag{1}$$

$$\boldsymbol{f * h = g^{-}} \tag{2}$$

$$\boldsymbol{f = D^{-1}(g^{-} * h)} \tag{3}$$

$$\boldsymbol{\eta = g - D^{-1}(g^{-} * h)} \tag{4}$$

where:

f is the original image or true image estimation,
g is the version that has been degraded through blurring (convolution $*$) by kernel *h* and
$g^{-}$is the deviated image from the original one (*f*)
η is the additional random noise or error, and
$\boldsymbol{D^{-1}}$is the de-convolution operator.

A new code using the MATLAB software was designed to deblur the image.The code was executed to eliminate theimage degradation and avoid the loss of information. The use of the code enables easy extraction of data from the images.

Fig. 2 shows the noisy neutron tomography (NT) image of a thyme plant. The unprocessed photo shows low quality image; therefore, advanced image processing technique was executed.

Fig. 2.NT of a thyme plant.

2.3 Explanation of imaging de-blur:

The 2D Gaussian function **G(*i*,*j*)** is defined as [8]:

$$G(i,j) = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{i^2+j^2}{2\sigma^2}\right) \quad (5)$$

where

σis the standard deviation and gives the width of the Gaussian bell curve, and ***i***, ***j*** are the Cartesian coordinates.

The Gaussian smoothing filter function can be written as:

$$G(i,J) = e^{-\frac{i^2+j^2}{2\sigma^2}} \quad (6)$$

The Gaussian function exhibited a property that was particularly useful for this model. This property indicated that the Gaussian smoothing filter was an effective low-pass filter, i.e., the filter that passes signals with a frequency lower than a certain cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency.The width, and hence the degree of smoothing (σ) or the cut-off frequency (f_c) values, were taken to be 0.93, 0.43 and 0.45, The output images of the code are shown in Fig. 3.

The figure shows that the image became enhanced by reducing the high frequency noise at f_c equal to 0.45, resulting in sharp denoisy edges.

Fig. 3.Processed image by Gaussian low-pass filter with different f_c values.

The high-quality image has not been accomplished yet.

2.4 Image smoothing by low-pass filter:

Low-pass filter was employed to remove high frequencies and reduce the noise from the image.The low-pass filter is:

$d=x^2+y^2$ (7)
$y(x,y)=I/(I+((d/f_c)^{(2*n)}))$ (8)

where:

x, ***y*** are the Cartesian coordinates.
y(x,y) is the modified image and
I is the original image,

The code was executed with different f_c, the order of the filter (n) was taken to be one. The resultant images are shown in Fig. 4 with f_c equal to 0.45, 0.5 and 0.55.

Fig. 4.Processed image by low-pass filter with different cut-off frequencies. The suppression of noise is pronounced with f_c= 0.50.

2.5 Imaging deblur by modified Butterworth filter:

The *n*thmodified Butterworth low-pass filter is given by:

$$B(x,y) = \frac{1}{\sqrt{1+[(x^2+y^2)/f_c]^{2n}}} \qquad (9)$$

The most appropriate value of n is 1. The advantage of this modified filter is that it does not exhibit a sharp discontinuity. The modified filter may be viewed as a transition between the two extremes of the ideal filter and the Gaussian filter. The definition of the cut-off frequency (f_c) is the main drawback of this filter.

The MATLAB code was executed for different f_c. (0.22, 0.2 and 0.17), the output images are shown in Fig. 5.

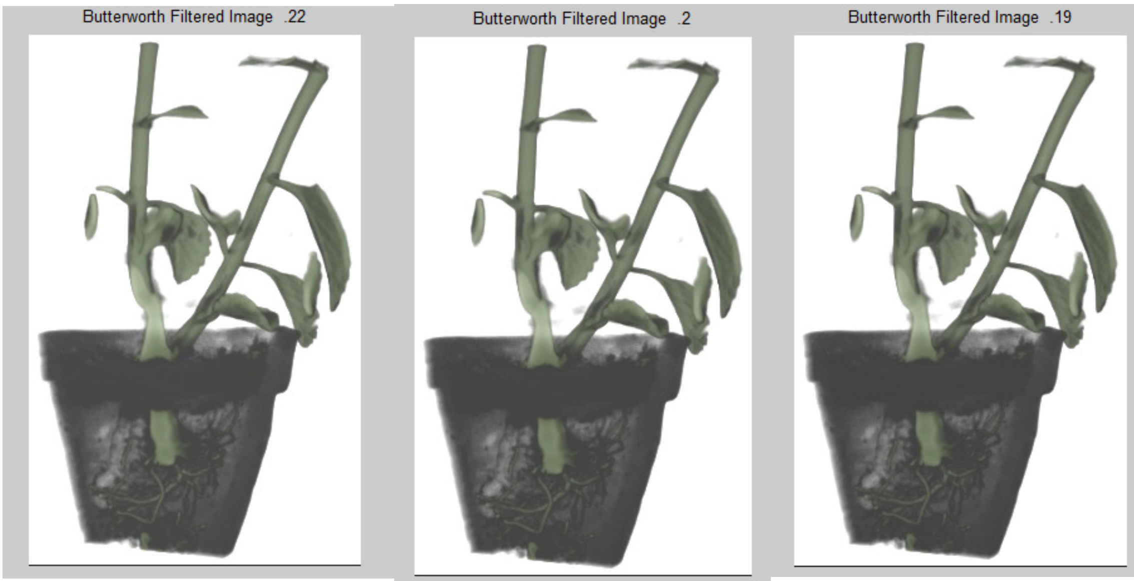

Fig. 5.Processed image by modified Butterworth low-pass filter with different f_c values.

3. Improving image quality by reducing the level of error (subtraction model):

The novelty of this work consists of executing a new code for noise depression based on Eq. (1). This method was designed to improve the image contrast and reduce the level of errors.

The model proposed that the original unprocessedNT image $g(x,y)$ can be represented as two images;the direct required image$f(x,y)$ or tomographic image that does not have any blurs,convolved with the blurred image $g^{-}(x,y)$ by the electronic components of the NR/T system, in addition to random noise or errors$\eta(x,y)$.

According to Eq. (1), the error$\eta(x,y)$ results from subtraction of the degraded NT image $g(x,y)$ and the de-convolution blind image$f(x,y)$. Since the degradation of image is unknown, the iterative technique was used to improve the image and reduce the factor of errors. The iterative method was executed to produce a sequence of images by subtracting the resultant error $\eta(x,y)$ from the degraded NT image $g(x,y)$.

The module can be mathematically expressed as:

$$\eta(x,y) = g(x,y) - f(x,y) \quad (10)$$
$$f(x,y) = g(x,y) - \eta(x,y) \quad (11)$$

The results are shown in Fig. 6. The module exhibits better performance for noise depression. The resultant image provided image improvement after three iterations, and more featuresin the root part appeared. Fig. 7 shows the flowchart of the iterative technique.

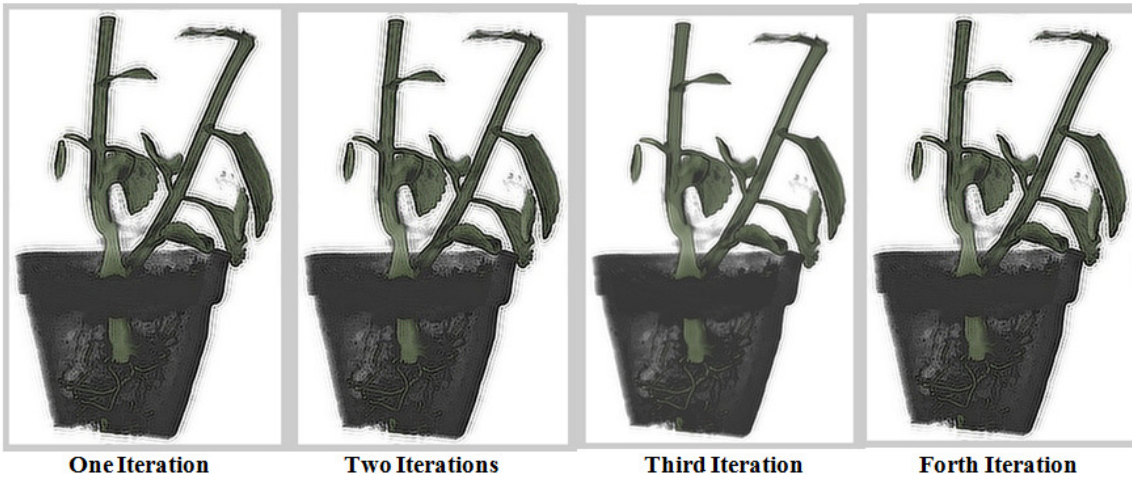

Fig. 6.Image improvement by the iteration technique.

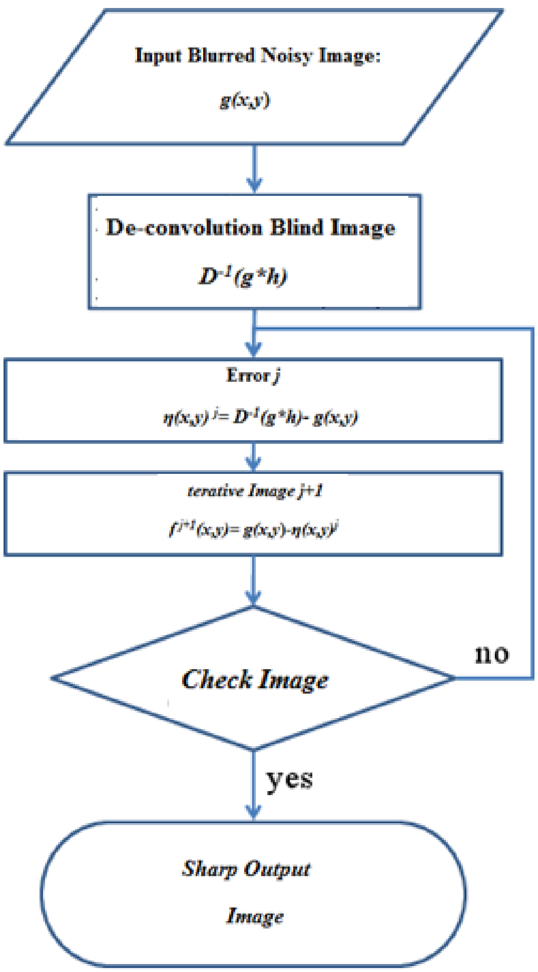

Fig. 7.Iteration technique flowchart.

4. Analysis of the results:

The proposed methods aimed to improve the image quality, increase the image details, and reduce the image noise by applying different digital filters. The proposed methods were based on removing the low frequency noise of the image by tuning the cut-off frequency. Then, the low frequency Gaussian image, Butterworth image and low-pass filter images were created.

The iteration model provided high quality image by creating a blind de-convolution image that subtracted from the unprocessed image to form first iterative noise depression image. The resultant image subtracted from the NT image to form the second iterative noise depression image. The iteration technique was executed until a degree of improvedimage was reached. The final image has information details and error suppression as well. Fig. 8 shows the enhancement in the root part of the plant.

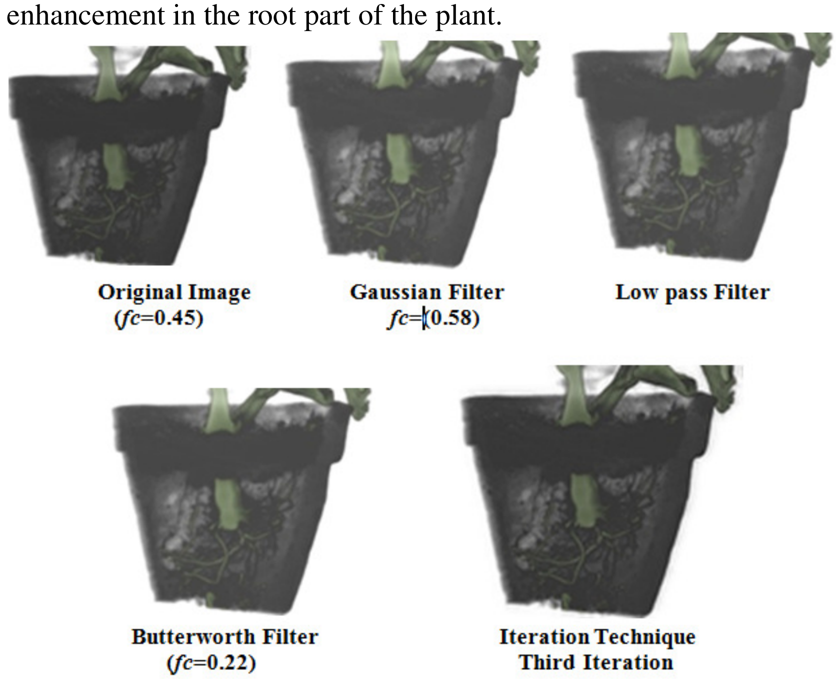

Fig. 8. Enhancement techniques in the root part of the plant. The iteration module is potentially effective.

Conclusions:

The MATLAB code is a useful software package for image processing and analysis. The software implements mathematical formulas and filters for image correction and enhancement. Low-pass Filters were applied in this work for improve the image. It was found that the software is a powerful tool for image enhancement.

An iteration technique module was designed to improve the image quality and reduce the image blur; this resulted in increased image details in comparison with the other techniques.

References:

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